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The feeding ecology of the velvet belly, *Etmopterus spinax* (Chondrichthyes: Squalidae), of the Adriatic Sea on the basis of its stomach contents

Abstract – The stomach contents of 78 velvet bellies, *Etmopterus spinax*, caught in the south-western Adriatic Sea as a result of one single trawl, were examined. The stomachs contained remains of 109 prey items belonging to at least 13 species: 54 teleosts, 36 crustaceans and 19 cephalopods. The classification of prey items according to their digestion stages (87.2% of items at very advanced digestion stage; 12.8% at very early stage), indicates that the velvet bellies had just resumed feeding after a resting period. Many remains consisted of mutilated prey and fragments bitten off from different regions of prey bodies, i.e. not only from their hind part. This observation is in agreement with the hypothesis that several velvet bellies attack simultaneously one large prey. Prey size ranged from «morsel size» items to large items. In conclusion, *E. spinax* is an aggressive opportunistic predator that preys mainly on nektonic animals, most probably by group-preying.

Riassunto – Ecologia alimentare del sagrì nero, *Etmopterus spinax* (Chondrichthyes: Squalidae), dell'Adriatico sulla base dei contenuti stomacali.

Sono stati esaminati i contenuti stomacali di 78 sagrì neri, *Etmopterus spinax*, raccolti in un'unica strascicata effettuata in pieno giorno, nell'Adriatico sud-occidentale. Sono stati individuati resti di almeno 109 prede: 54 teleostei, 36 crostacei e 19 cefalopodi appartenenti ad almeno 13 specie diverse. L'87,2% delle prede era in avanzatissimo stadio di digestione. La bassa percentuale di organismi poco digeriti (12,8%) indica che gli squaletti erano in fase di ripresa dell'attività alimentare dopo un periodo di stasi. Delle 14 prede ingerite da breve tempo, ben 10 erano rappresentate da esemplari mutilati o da frammenti strappati a morsi da diverse regioni del corpo; questo fatto corrobora l'ipotesi che il sagrì nero conduca predazione di gruppo. La varietà delle prede e la capacità di aggredire esemplari tanto a «dimensione di boccone» quanto relativamente grandi evidenziano che *E. spinax* è un predatore opportunista e aggressivo che si nutre prevalentemente di animali nectonici, molto probabilmente aggredendoli in gruppo.

Key words: Chondrichthyes, *Etmopterus spinax*, feeding, predation, Adriatic Sea.

Introduction

The velvet belly, *Etmopterus spinax* (Linnaeus, 1758) (Chondrichthyes: Squalidae), is one of the smallest sharks in the eastern Atlantic-Mediterranean area; its length-at-maturity ranges from 28 to 36 cm, its maximum length is 60 cm (Bauchot, 1987). It lives on the shelf and slope, from 70 to

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2,000 m depth (McEachran & Branstetter, 1984). The feeding habits of the velvet belly in the western Mediterranean Sea have been studied by Relini Orsi & Wurtz (1977), Macpherson (1980), and Wurtz & Vacchi (1981).

According to these studies, the velvet belly is an opportunistic predator that feeds mostly on nektonic bony fishes, crustaceans and cephalopods. In particular, Wurtz & Vacchi (1981) observed its circadian feeding periodicity and Macpherson (1980) showed the seasonal changes in its diet; furthermore the latter author suggested that velvet bellies carry out group-predation. The competition for food between *E. spinax* and other syntopic chondrichthyans was discussed by Macpherson (1980) and Capapé (1989).

As regards southern Adriatic velvet bellies, only the cephalopods found in their stomach contents have been taken into account (Bello, 1997a).

This paper deals with the stomach contents of a batch of velvet bellies caught in a single trawl in the south-western Adriatic Sea. The main purpose of this study is to acquire information on the mode of preying of *E. spinax*.

Materials and methods

The velvet bellies were caught off Mola di Bari (south-western Adriatic Sea) by a boat trawling at 495-560 m of depth, from 10:15 a.m. to 12:15 p.m. on the 18 March 1994. The 78 specimens, 34 males and 44 females, ranged from 11.9 to 28.7 cm in total length and from 5.8 to 101.4 g in weight (without stomach contents). All of them were sexually immature.

The velvet bellies were processed in the two days following their capture, during which time they were kept at about 0 °C. Each specimen was measured (total length and weight) and sexed before removing its stomach.

The stomach contents were weighed (total weight and, whenever possible, individual prey weight), sorted out and identified to the lowest possible taxon. To describe the digestion conditions of prey items, a three-step scale was used, where stage A is the least digested (prey at early digestion stages, retaining most body features) and stage C is the most digested (prey represented by hard part remains only) (Bello, 1997a).

In addition to the computation of the usual indices for stomach contents analysis (numerical percentage, vacuity coefficient, frequency of occurrence), the gastric index $Ig_i = [P_s / (P_c - P_s)] \times 100$ – where P_s is the stomach content weight and P_c is the weight of the whole shark – was calculated. In order to compare the quantity of food found in the stomachs of male and female velvet bellies, the gastric indices were Log-transformed, $Ig^*_i = \ln(Ig_i + 1)$, to overcome their positively skewed distribution, and their means for males and females compared with each other by the analysis of variance. No index based on the weight or volume of individual prey items (Rosecchi & Nouaze, 1987) was calculated, due to the low number of prey items suitable for measurement.

To estimate the width of the alimentary niche, Levins' B index was computed, $B = 1/\sum p^2$, where p is the numerical proportion of each prey species (Krebs, 1989).

Results

No statistically significant difference was found between the proportions of empty stomachs of males (6/34) and females (7/44) velvet bellies (χ^2 =

0.011; $df = 1$; P = ns). Furthermore, no significant difference was found between the mean gastric indices for males and females: $\overline{Ig}^*_m = 0.789$; $\overline{Ig}^*_f = 0.956$; $F = 1.388$; df = 43 and 33; P = ns. Hence, the data for the two sexes were pooled. The overall vacuity coefficient is V = 16.67% (13/78). The overall mean gastric index is $\overline{Ig}^* = 0.883$, from which $\overline{Ig} = 1.42$ was derived (this value is the geometric mean of the individual Ig_i values).

One-hundred-nine prey items were counted and ascribed to 13 taxa (Table 1). The arm fragment of a brittle star and a grinding plate of a cephalaspidean gastropod were not taken into account since they might have been ingested accidentally. Their occurrence, however, shows that the velvet belly is capable of taking food from the bottom.

Concerning the identified prey items (n = 33; 30.3% of prey), the numerical occurrence of each prey species is fairly low, 1 to 4 specimens, with the exception of *Heteroteuthis dispar* (10 specimens). Accordingly, the value of niche width, $B = 7.12$, is moderately high. All identified items, except the brittle star and gastropod, belong to nektonic species.

A high percentage of prey (87.2%) were at an advanced stage of digestion (stage C); for instance, most bony fish remains consisted of tiny fragments containing guanine (a compound found in dermal chromatophores) and many crustaceans were represented by fragments of esoskeleton and compound eyes. This fact explains the large fractions of unidentified bony fishes and crustaceans (88.9% and 69.4%, respectively). On the contrary, 84% of cephalopods were identified to the species level, thanks to the permanence of their beaks in the velvet belly stomachs.

No prey item was at an intermediate digestion stage (B).

Only 14 prey items (12.8%) were at an early stage of digestion (Table 2). Their weights ranged from 0.3 g (an euphausiid) to 16.8 g (the trunk of a specimen of *Lampanyctus crocodilus* lacking head and tail) (Fig. 1). Ten out of these 14 items consisted of bitten remains. The largest morsel was from a fish 21 cm long (estimated length), i.e. the above mentioned fragment of *L. crocodilus*; it was found in the stomach of a small velvet belly, 22.9 cm long, weighing 41.9 g.

Discussion

The feeding spectrum of *Etmopterus spinax* in the southern Adriatic Sea is largely composed of nektonic bony fishes, cephalopods, decapod and euphausiid crustaceans; this corresponds to the spectra reported by Relini Orsi & Wurtz (1977) and Wurtz & Vacchi (1981) for the Ligurian Sea and by Macpherson (1980) for the Catalan Sea.

The composition of stomach contents according to digestion stage (87.2% of prey items at a very advanced digestion stage; 12.8% at an early digestion stage) indicates that velvet bellies had resumed feeding just about the time of their sampling (10:15 a.m. - 12:15 p.m.) after a period of rest. This fact is in agreement with the feeding pattern described by Wurtz & Vacchi (1981), according to which *E. spinax* feeds mostly during full daytime. In addition the comparatively high vacuity coefficient (V = 16.7%) supports the hypothesis of intermittent feeding activity (Ellis et al., 1996).

The bitten condition of many prey items, the comparatively large size of some of them, and the body region from which fragments were bitten off,

Table 1 - List of prey found in the stomachs of velvet belly. Number (*N*), relative number (*N*%) and percent frequency (*F*%) for each prey species; in square backets, the same for the three main taxa.

	N	*N*%	*F*%
OSTEICHTHYES [*N* = 54; *N*% = 49.54; *F*% = 63.08]			
Stomiidae			
Stomias boa (Risso, 1810)	1	0.92	1.54
Myctophidae			
Benthosema glaciale (Reinhardt, 1837)	1	0.92	1.54
Lampanyctus crocodilus (Risso, 1810)	1	0.92	1.54
mictophid unid.	3	2.75	4.62
bony fishes unid.	48	44.04	(55.38)
CRUSTACEA [*N* = 36; *N*% = 33.03; *F*% = 66.15]			
EUPHAUSIACEA			
Euphausiidae			
Nematoscelis megalops G.O. Sars, 1883	1	0.92	1.54
euphausiid unid.	2	1.83	3.08
DECAPODA			
Aristeidae			
Aristaeomorpha foliacea (Risso, 1827)	2	1.83	3.08
Sergestidae			
Sergestes sp.	2	1.83	1.54
Pasiphaeidae			
Pasiphaea sivado (Risso, 1816)	1	0.92	1.54
Pasiphaea multidentata Esmark, 1866	1	0.92	1.54
Alpheidae			
Alpheus glaber (Olivi, 1792)	1	0.92	1.54
Crangonidae			
Pontocaris lacazei (Gourret, 1887)	1	0.92	1.54
crustaceans unid.	25	22.94	(30.77)
CEPHALOPODA [*N* = 19; *N*% = 17.43; *F*% = 24.62]			
Sepiolidae			
Heteroteuthis dispar (Rüppell, 1844)	10	9.17	13.85
Enoploteuthidae			
Abralia verany (Rüppell, 1844)	4	3.67	6.15
Histioteuthidae			
Histioteuthis bonnellii (Férussac, 1835)	2	1.83	3.08
cephalopods unid.	3	2.75	(4.62)
TOTAL PREY ITEMS	109		

Table 2 - Condition of prey items at an early stage of digestion; *tl* = total length; *fl* = length of the fragment.

prey	weight (g)	condition
Stomias boa juv.	1.6	whole, *tl* = 9 cm
Benthosema glaciale	1.8	without caudal part, *fl* = 3.1 cm
Lampanyctus crocodilus	16.8	trunk without head and tail, *fl* = 11 cm
unidentified bony fish	0.6	fragment of trunk, *fl* = 0.9 cm
unidentified bony fish	0.2	dorsal fin
Nematoscelis megalops	0.3	whole, *tl* = 2 cm
Aristaemorpha foliacea	5.7	posterior part, *fl* = 5 cm
Aristaemorpha foliacea	1.2	fragment of abdomen
Pasiphaea sivado	1.9	whole, *tl* = 6.5 cm
Pasiphaea multidentata	0.8	trunk with a few pereiopods
Pontocaris lacazei	1.3	whole
Heteroteuthis dispar	1.2	fragment of mantle
Heteroteuthis dispar	1.0	fragment of mantle
Histioteuthis bonnellii	3.0	head

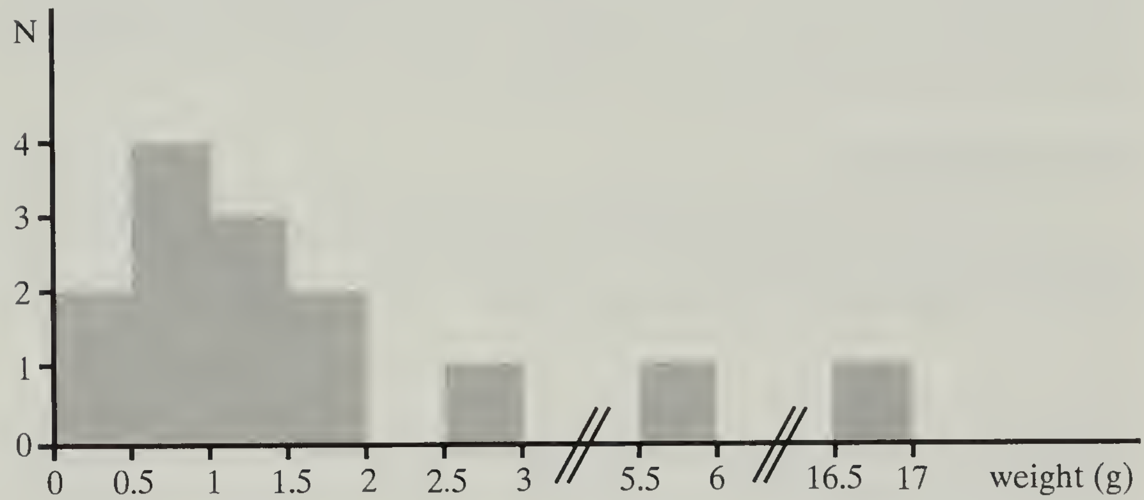

Fig. 1 - Weight frequency distribution of prey items at an early stage of digestion.

other than the hind region (Table 2), are in agreement with the hypothesis that velvet bellies carry out group-predation (Macpherson, 1980), attacking simultaneously the prey from several sides (see also Springer [1967] on group-preying in *Etmopterus virens*).

As regards the mode of preying of other Mediterranean small-size, sedentary sharks, Macpherson (1980) and Carrassón et al. (1992) report that the stomachs of *Galeus malastomus* (Scyliorhinidae) sometimes – less frequently than *E. spinax* – contain pieces of prey too large in relation to the predator's size, which perhaps implies that this species also hunts in group. In addition, Bello (1995) pointed out that *G. melastomus* chase and attack its prey mainly from behind. Large food remains (e.g. cetacean blubber) found in the stomach contents of *Centroscymnus coelolepis* (Squalidae) are attributable to scavenging habits (Carrassón et al., 1992). Lastly, no remains of large-size prey are reported by Macpherson (1980) in the stomach contents of *Dalatias licha* (Squalidae).

In conclusion, the velvet belly is an aggressive opportunistic predator that preys mostly on nektonic animals, both small («morsel size») and large, most probably by group-preying. Also the moderately high value of the alimentary niche width, $B = 7.12$, is in agreement with the above statement (*cf.* the list of B values for ten elasmobranchs in Ellis et al. [1996] ranging from 1.42 to 9.65).

The most frequent prey species found in the stomachs of southern Adriatic velvet bellies is the sepiolid squid *Heteroteuthis dispar*, which plays an important role in pelagic food webs; detailed accounts about this cephalopod are reported by Bello (1995) and Sartor & De Ranieri (1995). The identified cephalopod species are considered rare. Yet, they were found to be rather common in the southern Adriatic Sea (as well as in other Mediterranean areas), thanks to the study of teuthophagous predators, including the velvet belly (Bello, 1997b). The identified crustaceans and bony fishes belong to common species, except the myctophid fish *Benthosema glaciale* that has been sporadically collected in the Adriatic Sea (Šoljan, 1975; Fabiano & Fabiano, 1977); incidentally, this species is not reported in the Adriatic Sea in widely used handbooks, such as «FNAM» (Hulley, 1984) and «Fiches FAO d'identification» (Bauchot, 1987).

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References

Bauchot M.-L., 1987 - Requins. Poissons osseux. In: Fiches FAO d'identification des espèces pour les besoins de la pêche. (Révision 1). Méditerranée et mer Noire. Zone de pêche 37. Vol. II. Vertébrés. Fischer W., Schneider M. & Bauchot M.-L. (eds.), FAO, Rome, pp. 767-843; 891-1422.

Bello G., 1995 - *Heteroteuhis dispar* (Cephalopoda: Sepiolidae) nella dieta di selaci demersali. Biol. Mar. Medit., *2(2)*: 211-215.

Bello G., 1997a - Cephalopods from the stomach contents of demersal chondrichthyans caught in the Adriatic Sea. Vie Milieu, *47*: 221-227.

Bello G., 1997b - Teuthophagous predators as collectors of oceanic cephalopods: the case of the Adriatic Sea. Boll. Malacol., *32*: 71-78.

Capapé C., 1989 - Les Sélaciens des côtes méditerranéennes: aspects généraux de leur écologie et exemples de peuplements. Océanis, *15*: 309-331.

Carrassón M., Stefanescu C. & Cartes J. E., 1992 - Diets and bathymetric distributions of two bathyal sharks of the Catalan deep sea (western Mediterranean). Mar. Ecol. Prog. Ser., *82*: 21-30.

Ellis J. R., Pawson M. G. & Shackley S. E., 1996 - The comparative feeding ecology of six species of shark and four species of ray (Elasmobranchii) in the north-east Atlantic. J. Mar. Biol. Ass. U.K., *76*: 89-106.

Fabiano M. & Fabiano A. M., 1977 - Pesci batifili raccolti nel corso delle campagne di pesca della N/R «S. Lo Bianco». Quad. Lab. Tecnol. Pesca, Ancona, *2*: 165-174.

Hulley P. A., 1984 - Myctophidae. In: Fishes of the North-eastern Atlantic and the Mediterranean. Vol. I. Whitehead P.J.P., Bauchot M.-L., Hureau J.-C., Nielsen J. & Tortonese E. (eds.), Unesco, Paris, pp. 429-483.

Krebs C. J., 1989 - Ecological methodology. Harper Collins, New York.

Macpherson E. 1980 - Régime alimentaire de *Galeus melastomus* Rafinesque, 1810 *Etmopterus spinax* (L., 1758) et *Scymnorhinus licha* (Bonnaterre, 1788) en Méditerranée occidentale. Vie Milieu, *30*: 139-148.

McEachran J. D. & Branstetter S., 1984 - Squalidae. In: Fishes of the North-eastern Atlantic and the Mediterranean. Vol. I. Whitehead P.J.P., Bauchot M.-L., Hureau J.-C., Nielsen J. & Tortonese E. (eds.), Unesco, Paris, pp. 128-147.

Relini Orsi L. & Wurtz M., 1977 - Patterns and overlap in the feeding of two selachians of bathyal fishing grounds in the Ligurian sea. Rapp. Comm. int. Mer Médit., *24(5)*: 89-94.

Rosecchi E. & Nouaze Y., 1987 - Comparaison de cinq indices alimentaires utilisés dans l'analyse des contenus stomacaux. Rev. Trav. Inst. Pêches marit., *49*: 111-123.

Sartor P. & De Ranieri S., 1995 - *Heteroteuthis dispar* (Ruppell, 1844) (Cephalopoda, Sepiolidae) nella dieta di due selaci batiali nel Mar Tirreno settentrionale. Biol. Mar. Medit., *2(2)*: 517-518.

Šoljan T., 1975 - I Pesci dell'Adriatico. A. Mondadori Ed., Milano.

Springer S., 1967 - Social organization of sharks populations. In: Sharks, Skates and Rays. Gilbert P. W., Matherson R. F. & Rall D. P. (eds.), John Hopkins Press, Baltimore, pp. 149-178.

Wurtz M. & Vacchi M., 1981 - Ricerca di cicli nittemerali nell'alimentazione di selaci batiali. Quad. Lab. Tecnol. Pesca, Ancona, *3, suppl. 1*: 155-164.